A multi-band VLA comparison of Normal and Extreme Star-Forming Galaxies in the Local Universe

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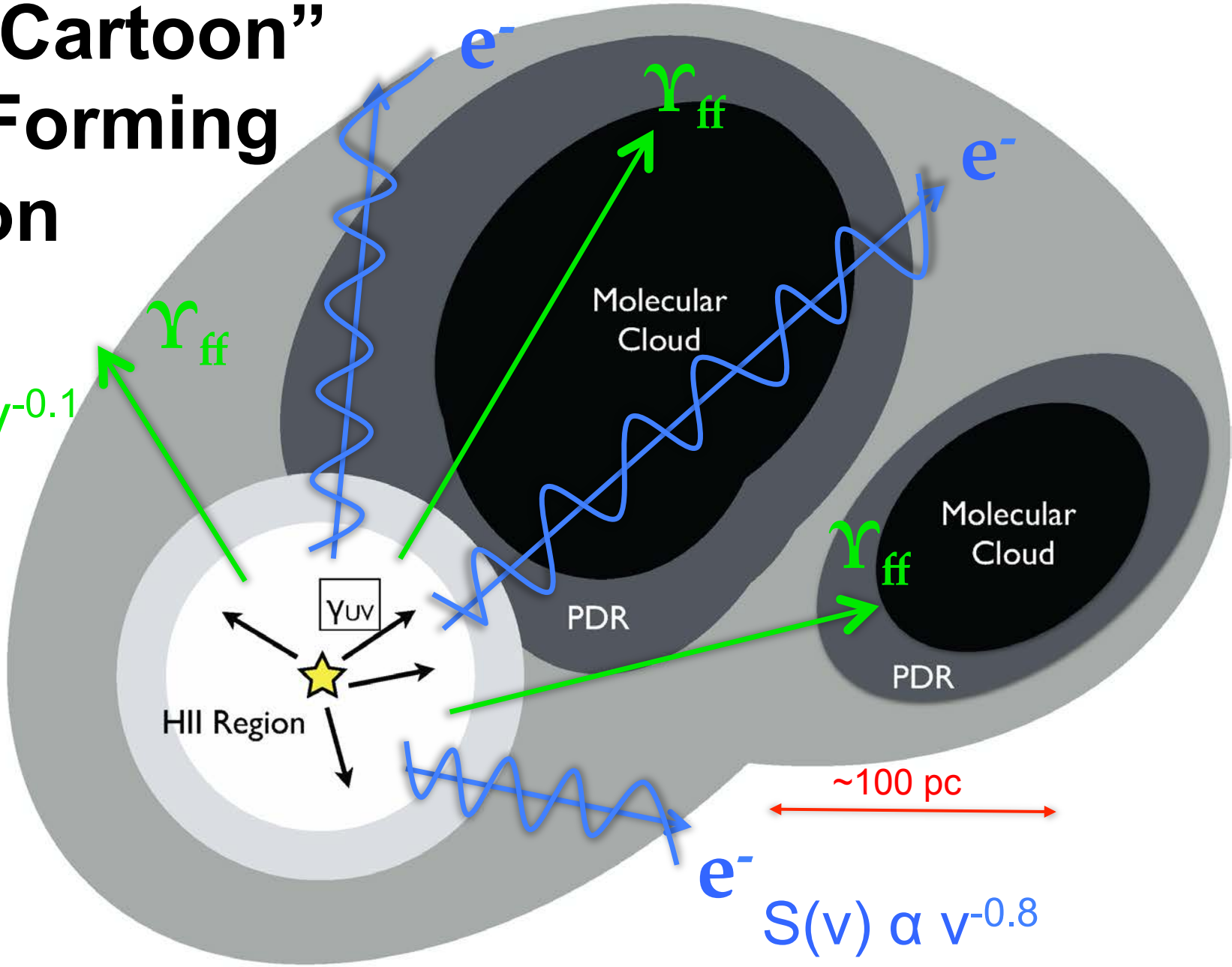
Our "Cartoon" Star-Forming Region

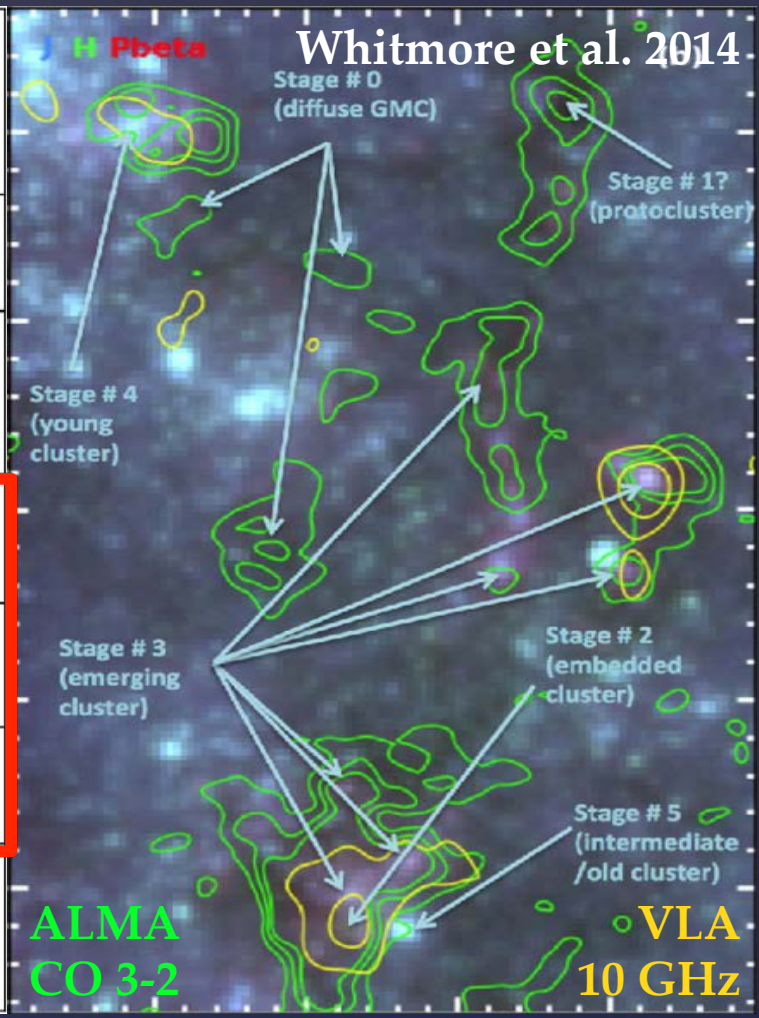


S(ν) α ν$^{-0.1}$

Courtesy of Aaron Evans

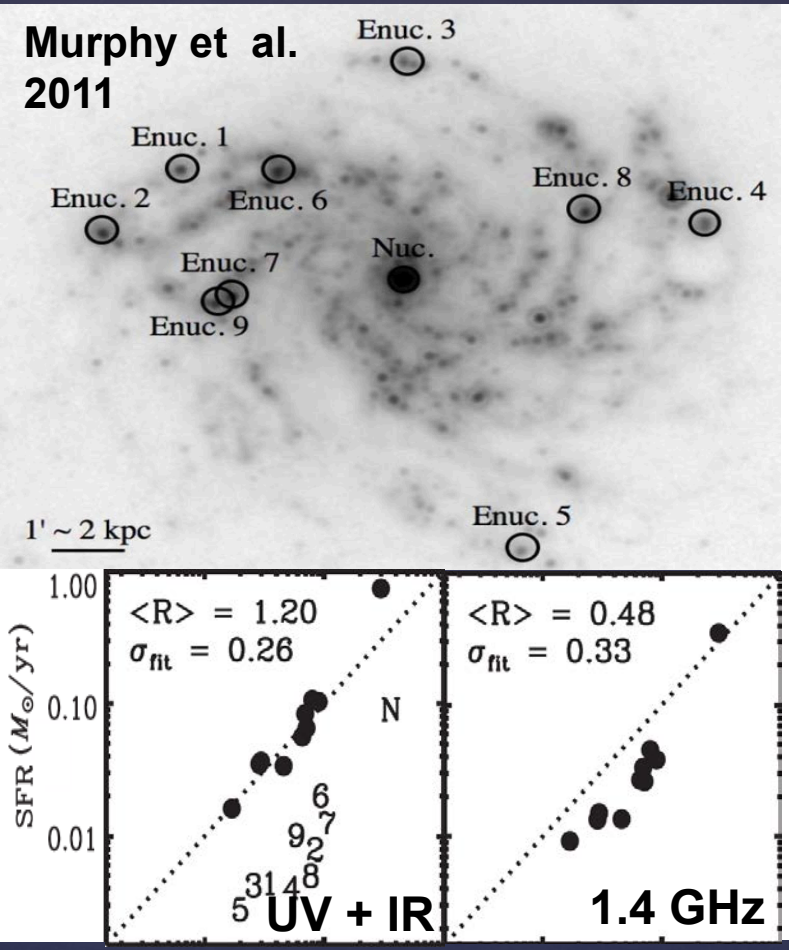
The Evolution of SF Regions within Galaxies

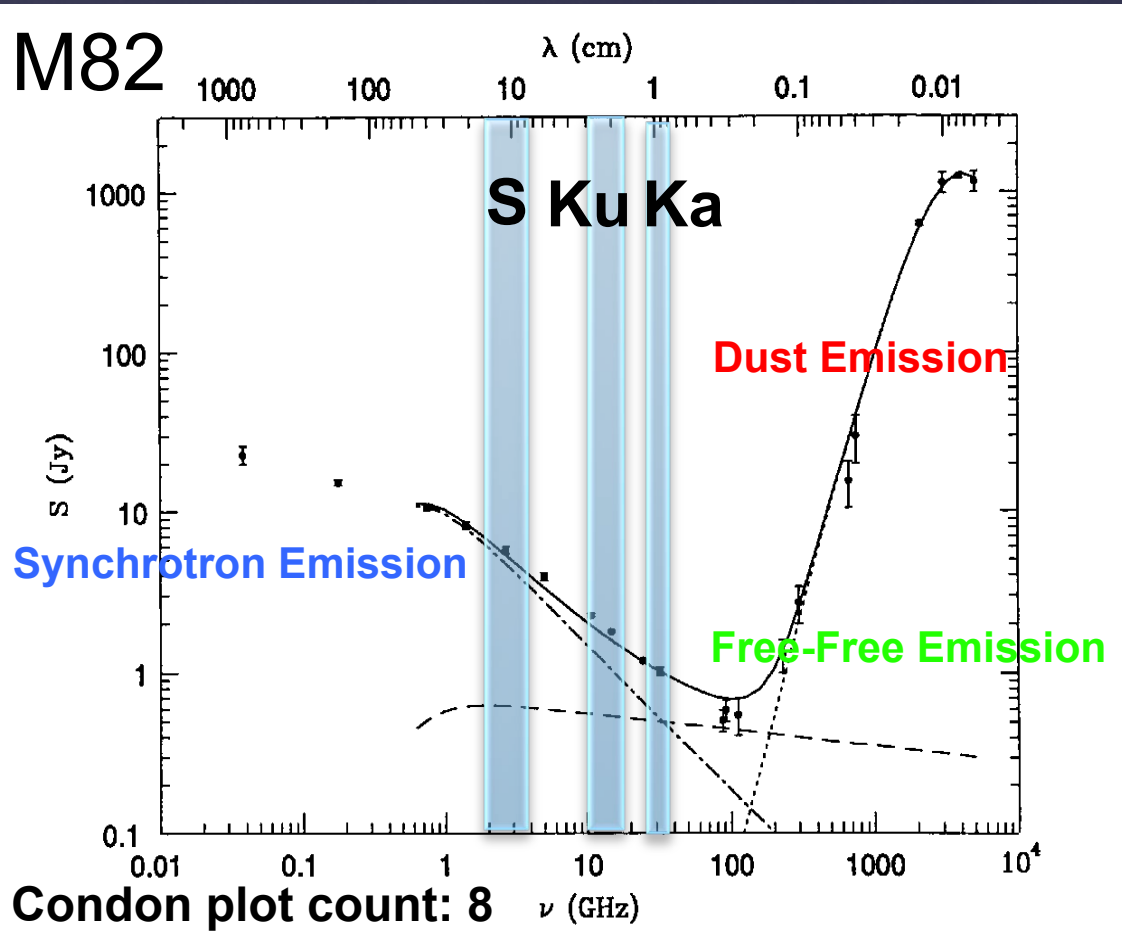
cluster formation and evolution stage	CO	Radio	Optical/ near-IR continuum	Optical/ near-IR line emission (e.g., Ha, Pa, Pb, ...)	Notes
Stage 0 (diffuse GMC)	Yes, diffuse	---	---	---	Turbulent equilibrium
Stage 1 (protocluster)	Yes, compact, bright	---	---	---	High pressure, grav. collapse, onset of star formation (< 0.1 Myr)
Stage 2 (embedded cluster)	Yes, compact > diffuse, bright	Yes, bright	---	Possible, compact, faint	Increasing star formation (0.1 - 1 Myr)
Stage 3 (emerging cluster)	Yes, diffuse, faint	Yes, moderate	Yes, faint, (Av > 1)	Possible, compact > bubble, bright	Removal of gas and dust (1 - 3 Myr)
Stage 4 (young cluster)	---	Yes, faint	Yes, bright, (Av < 1)	Possible, bubble, moderate	ISM feedback (3 -10 Myr)
Stage 5 (intermediate/old cluster)	---	---	Yes, moderate	---	Spectral dimming, evaporation (> 10 Myr)



- How do these properties for normal galaxies scale to the more extreme environments in Luminous Infrared Galaxies?
- What are the relative contributions of thermal and non-thermal emission in *individual* regions in galaxies?

The Star Formation in Radio Survey: PI E. Murphy

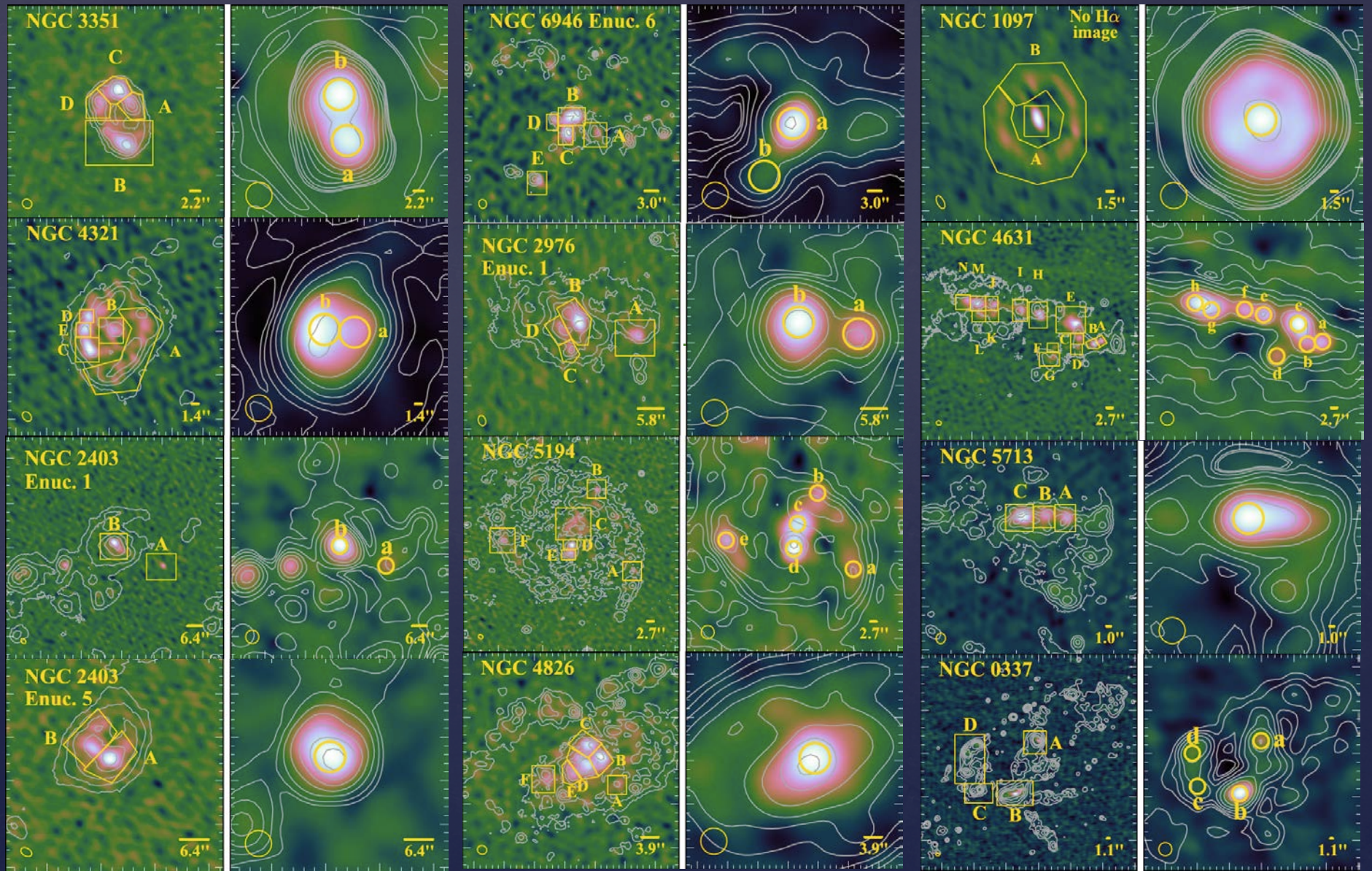




- The UV + IR calibration for the enuc regions compare well, but over predicts the nucleus. The 1.4 GHz calibration are low (except nucleus) showing the GBT beam size requires CR diffusion dependence
- **SFRS:** 118 nuclei and star-forming regions in 56 galaxies from SINGS/ KINGFISH (Kennicutt et al. 2011) at physical scales of 30 - 300 pc

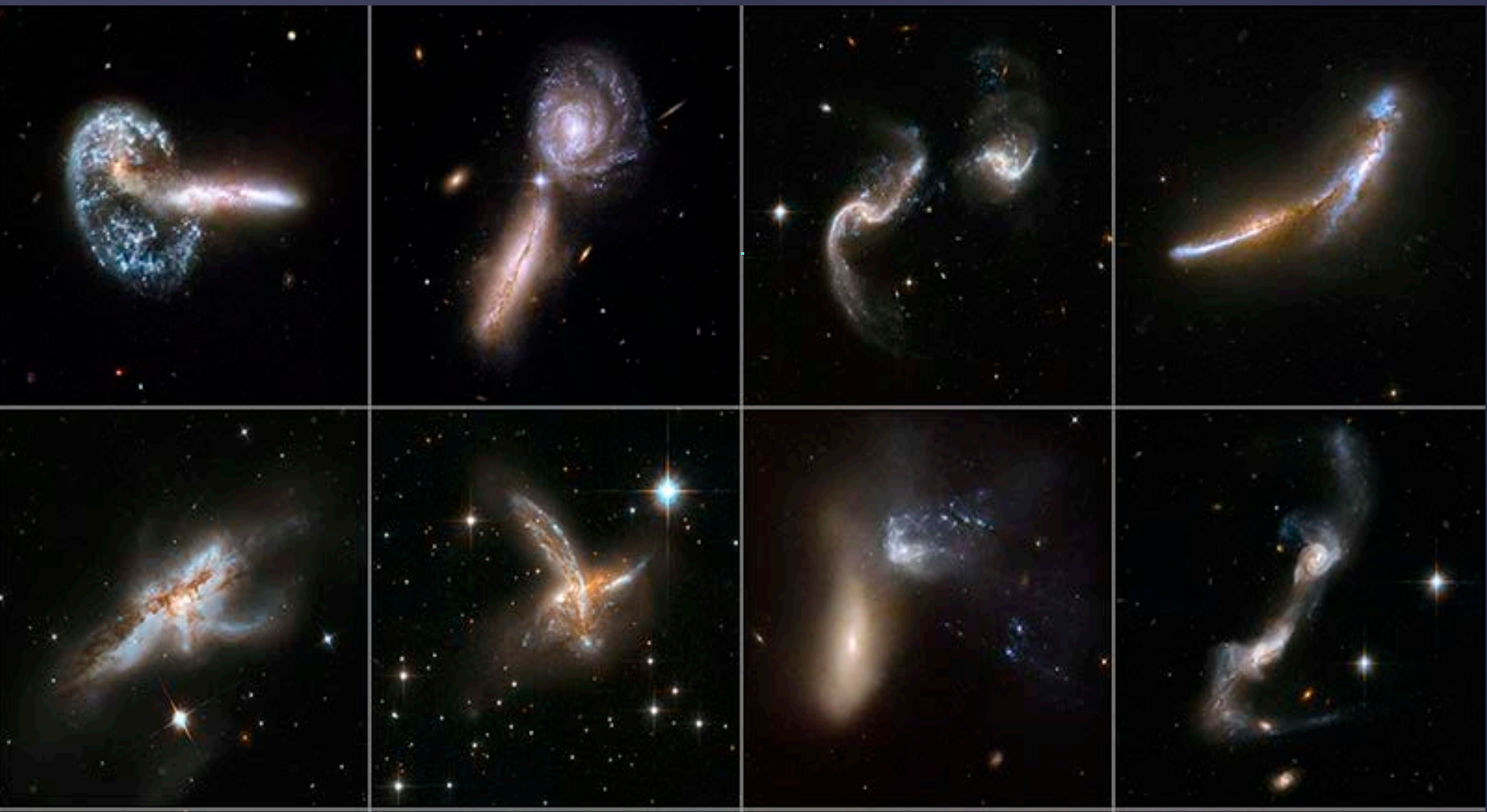
SFRS 33 GHz Image Gallery

Murphy, Dong, Linden et al. 2017, in prep



The VLA Great Observatories All-Sky LIRG Survey (VLA-GOALS): Linden et al.

- **VLA Equatorial Survey:** 71 U/LIRGs, 34 selected by 6.2um PAH EW as being SF dominated (Stierwalt et al. 2013). Same angular resolution and bands as SFRS



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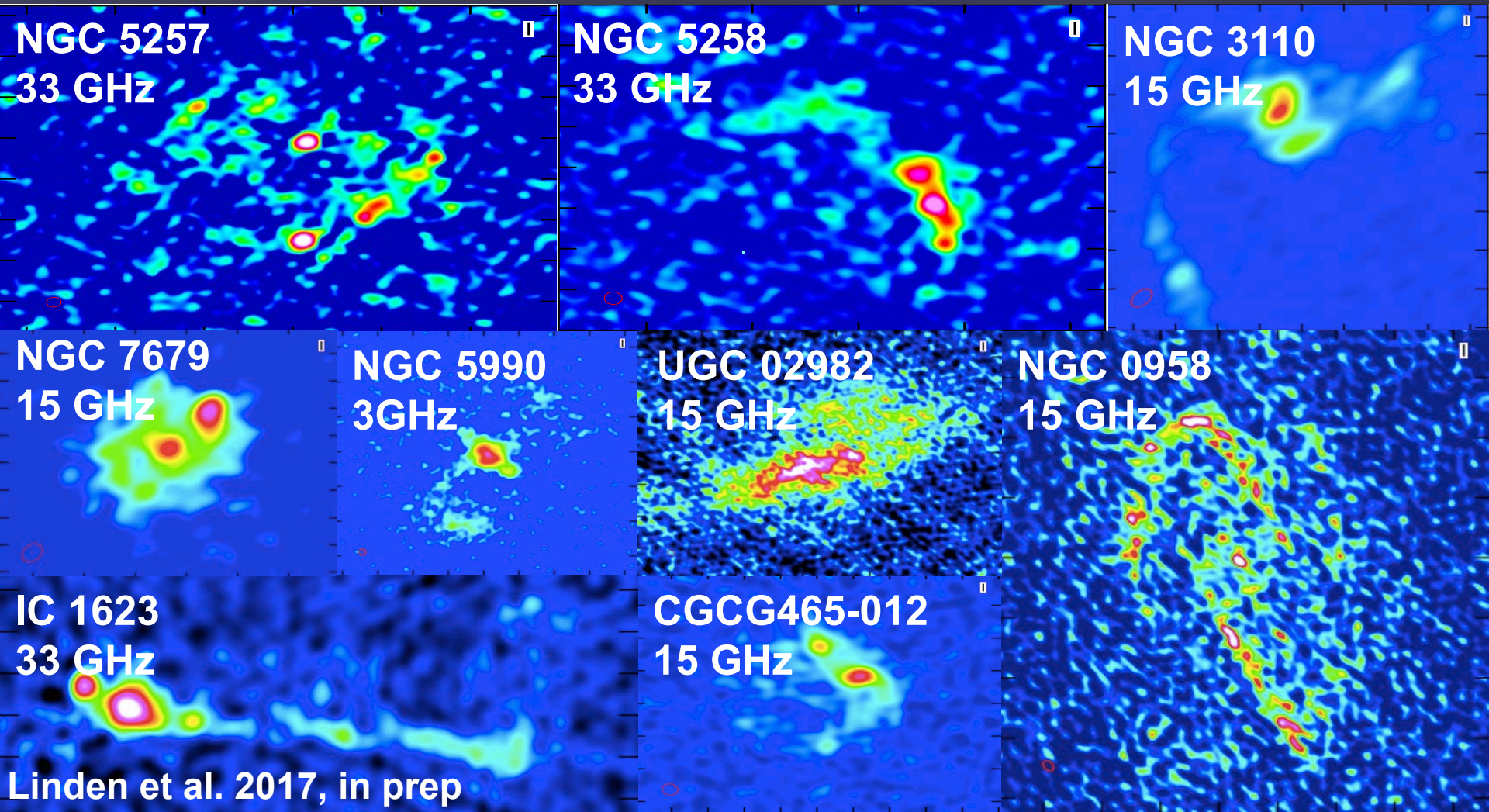
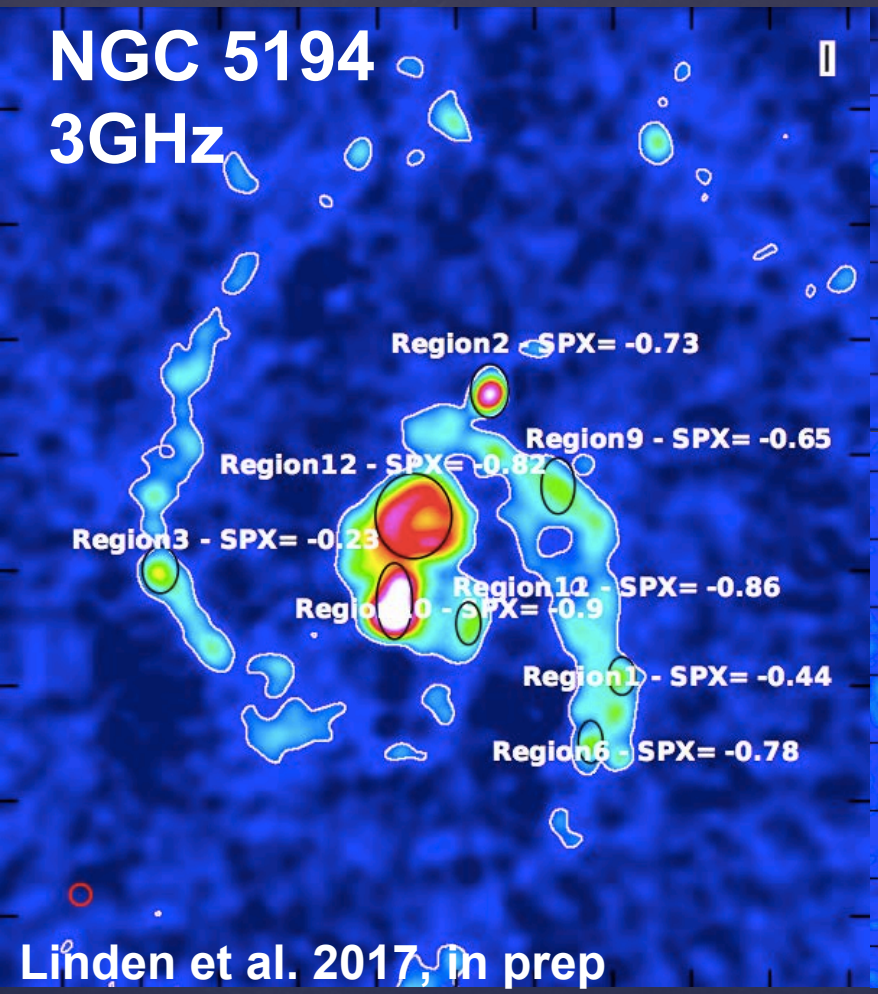
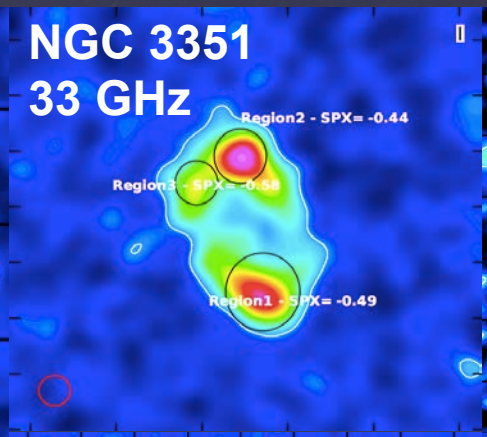
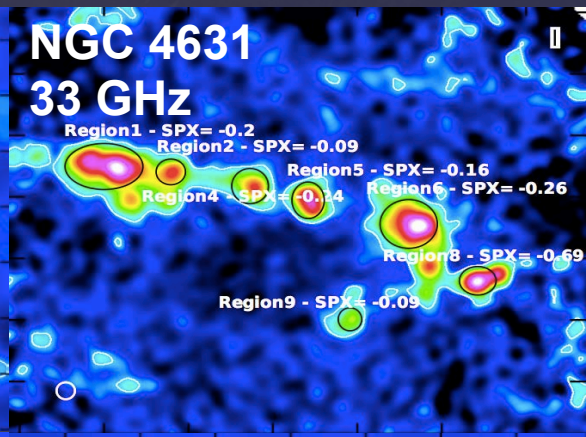
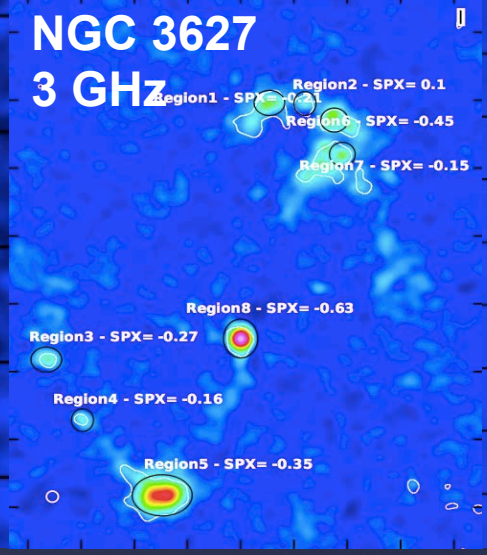


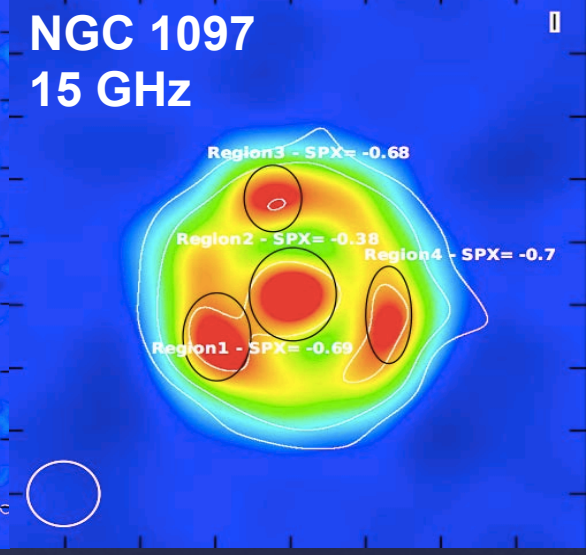
Preliminary SPX Results for SFRS







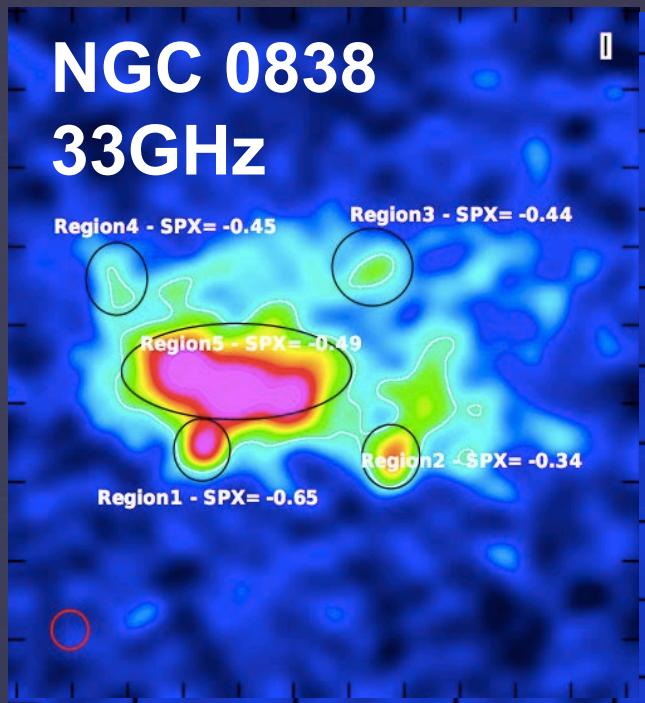


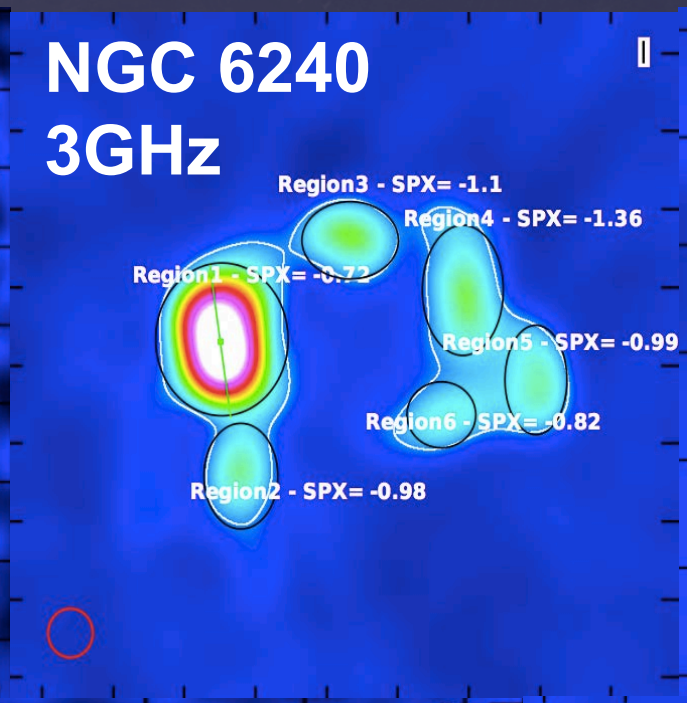


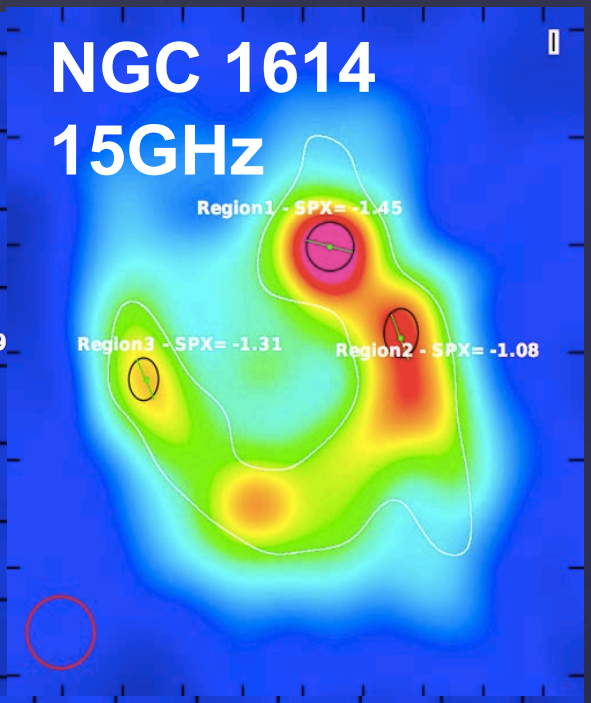
Linden et al. 2017, in prep

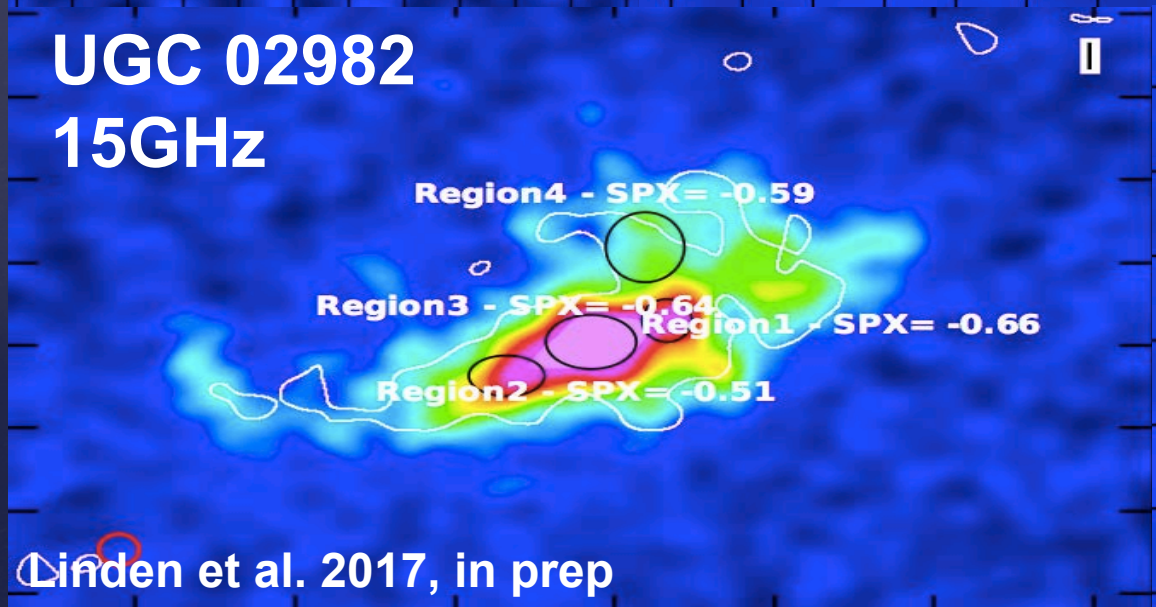
- Evidence of large-scale non-thermal emission surrounding nuclear SF regions in all galaxies
- HII regions further from the nucleus have flatter SPXs compared to HII regions closer to the nucleus

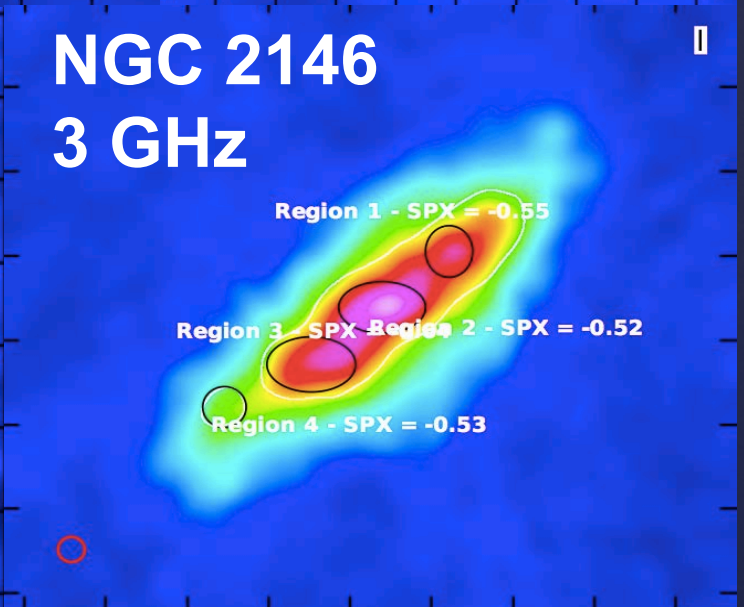
Preliminary SPX Results for GOALS





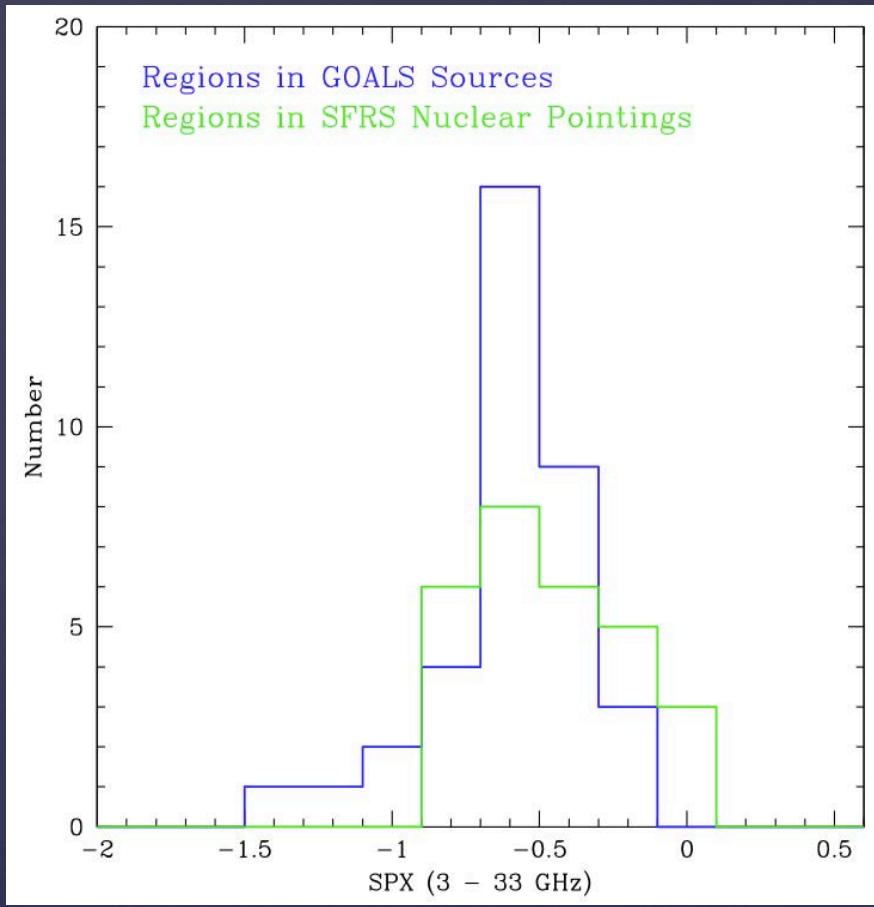


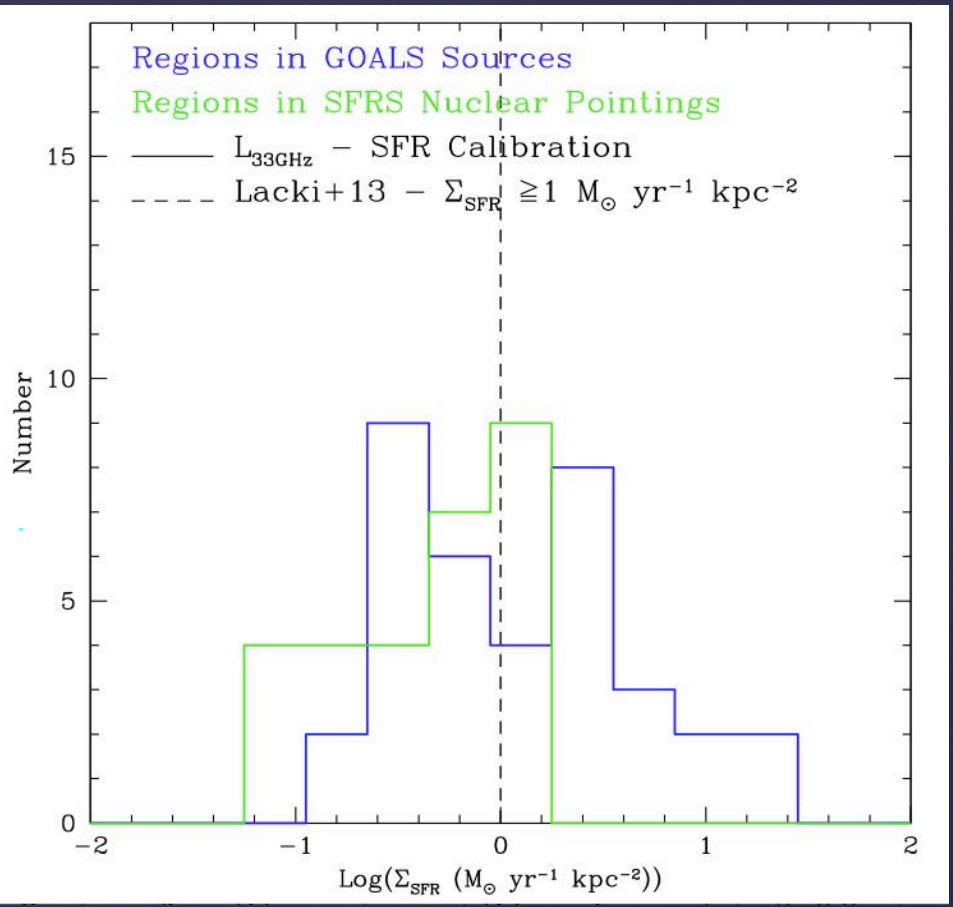




Linden et al. 2017, in prep

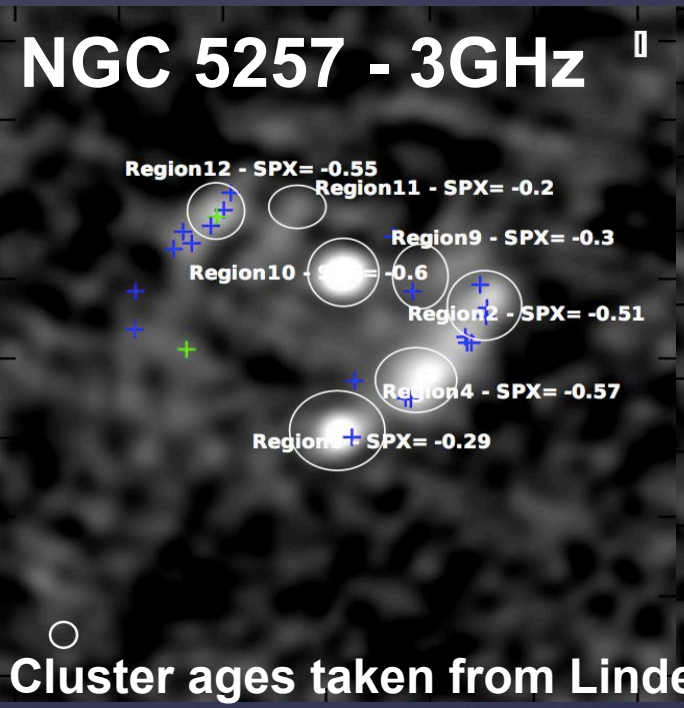
Comparing GOALS to SFRS Sources

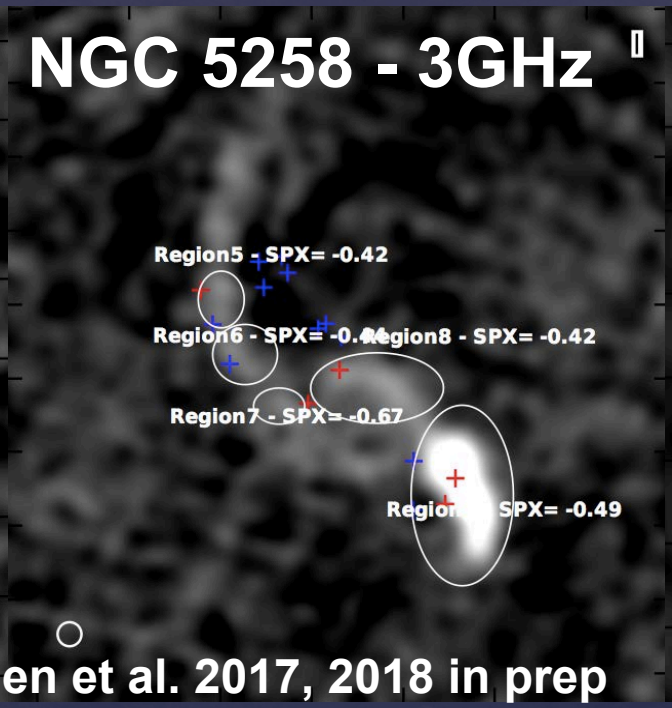


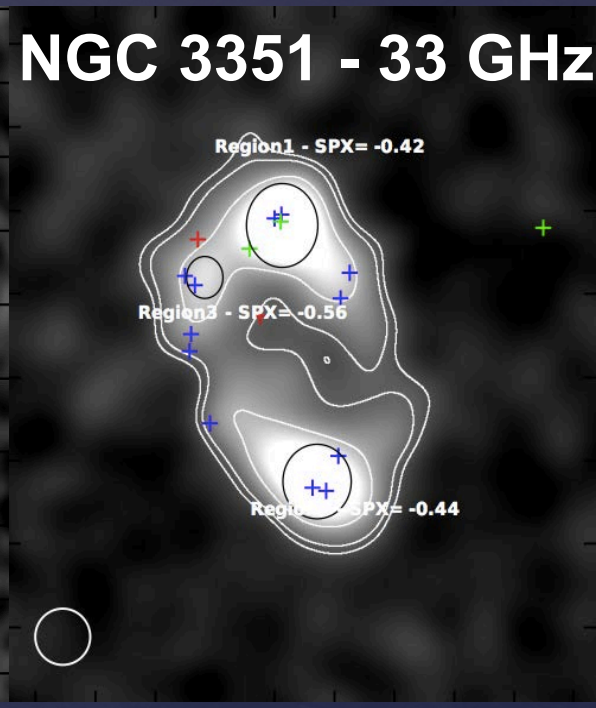


- The spectral indices and the SFR surface densities of ~ 1 kpc-size regions in LIRGs greatly overlap with that of ~100 pc-size nuclear regions of SFRS galaxies
- SF regions in LIRGs appear to be scaled-up versions of the nuclear regions of local star-forming galaxies

Young Massive Clusters in Normal and Extreme Environments: Linden et al.







Cluster ages taken from Linden et al. 2017, 2018 in prep

- Our Spectral index measurements agree qualitatively with SB99 starburst models of the 33 GHz radio flux
- The radio spectral shape can be an accurate probe of massive cluster formation within **individual** star-forming regions (~200pc)

Summary

- SFRS has mapped the 3-33 GHz continuum emission in 112 nuclear and extranuclear star-forming regions in galaxies in SINGS
- With these datasets we study the fraction of each emission mechanism and current SFR of individual regions within galaxies, free from issues related to dust extinction
- I will also be comparing our results to a matched set of Luminous Infrared Galaxies with full optical-Far IR complementary data from GOALS
- Initial results indicate 1kpc sized regions of LIRGs are ‘scaled-up’ versions of 100 pc nuclear regions in SFRS

Collaborators and Acknowledgements

Aaron Evans – University of Virginia, NRAO

Eric Murphy – NRAO

Emmanuel Momjian - NRAO

Yiqing Song – University of Virginia

Dillon Dong– Caltech

Lee Armus – IPAC, Caltech

Sabrina Stierwalt – NRAO

George Privon – Universidad de Concepcion, Chile

Tanio Díaz-Santos – Universidad Diego Portales

Kirstin Larson – IPAC, Caltech

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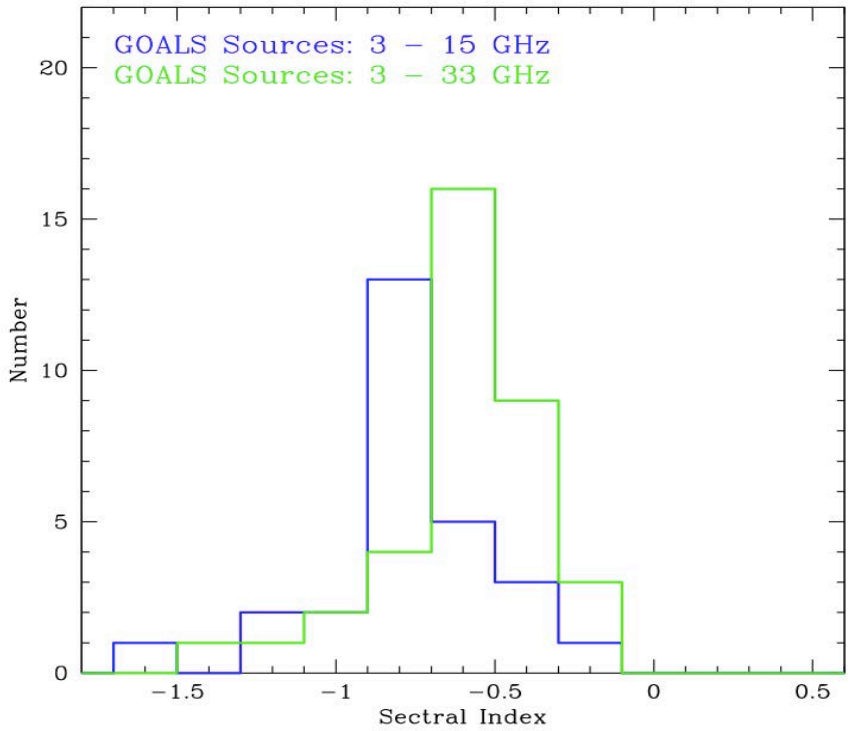
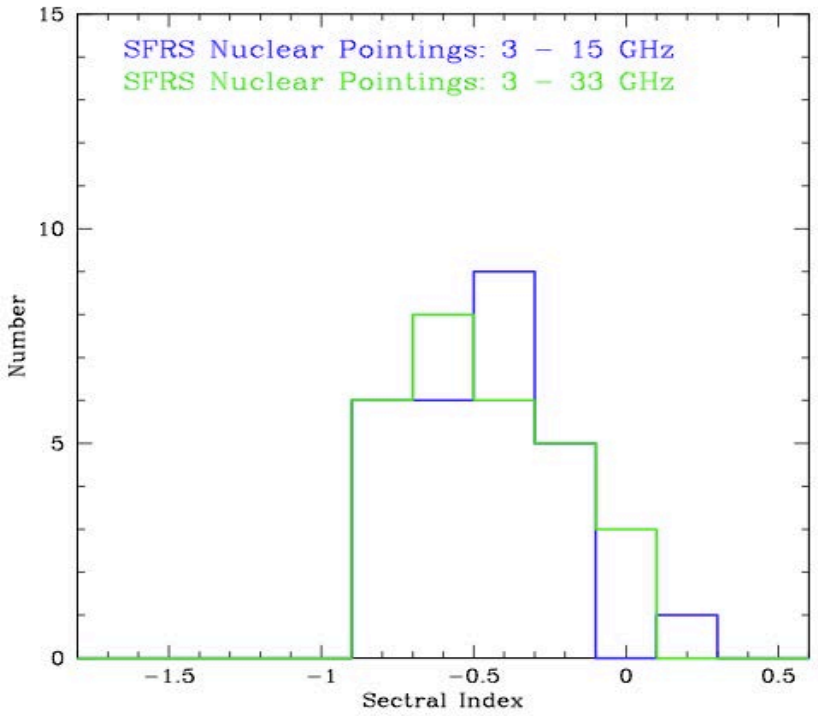
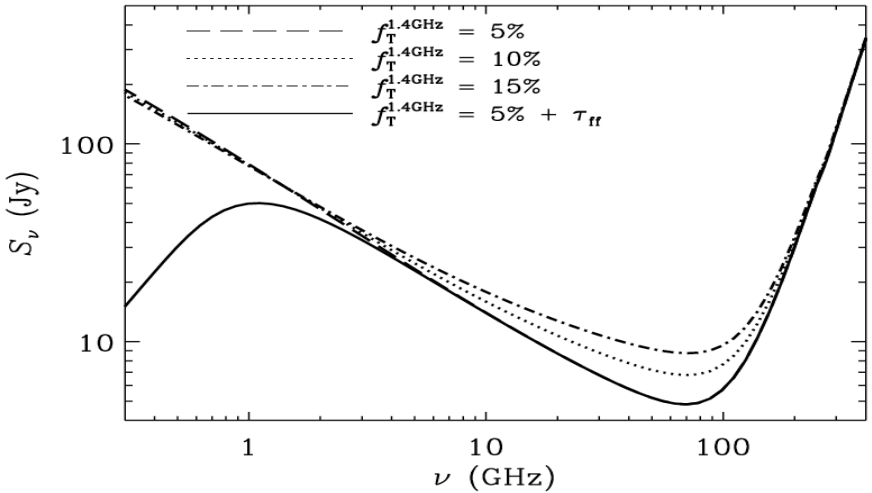
Determining The Impact of Free- Free Absorption in our Spectrum

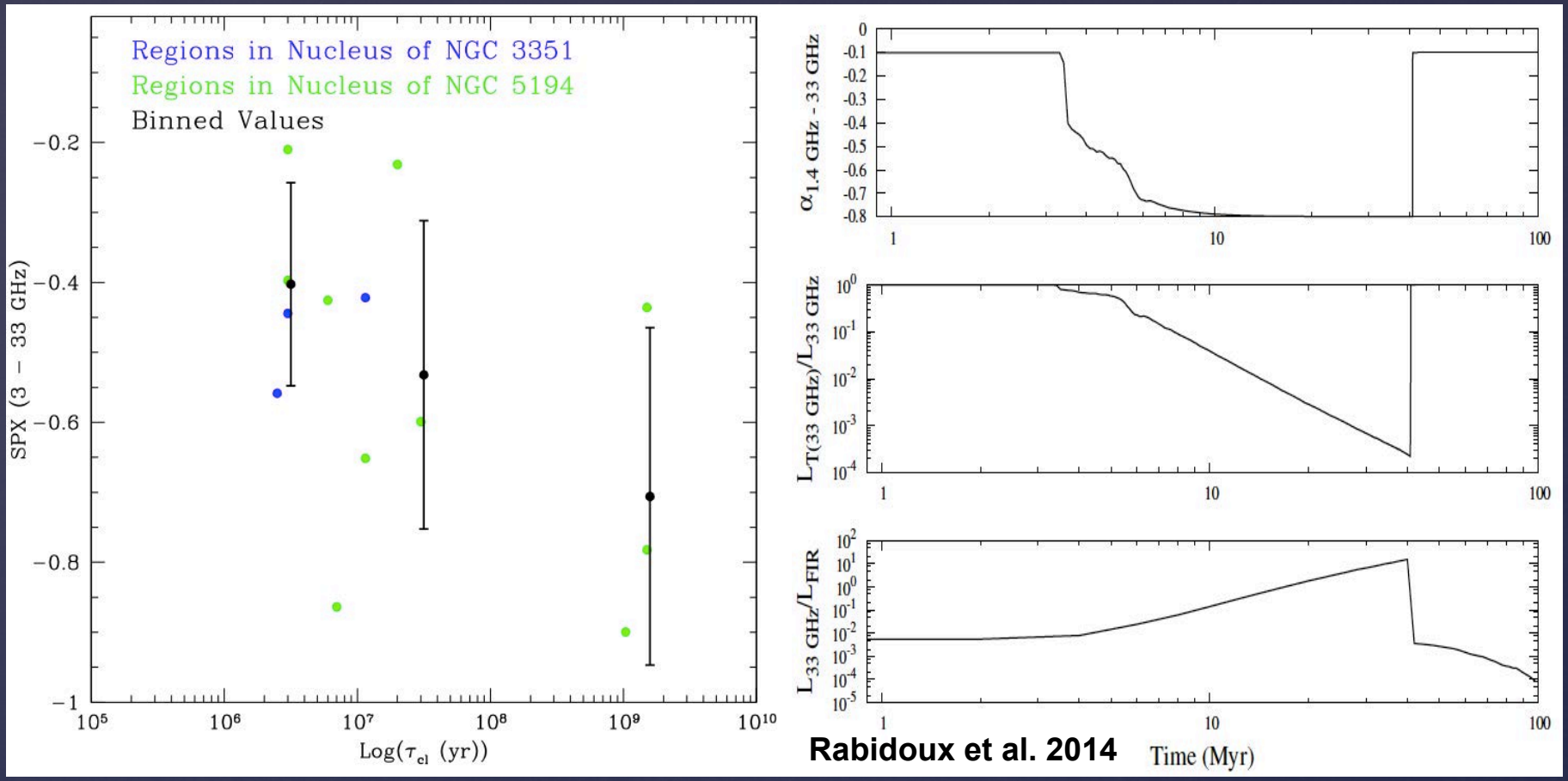






- No major evidence of free-free absorption in SFRS thus far. Overall we expect that on a region-by-region basis the effect is minimal, but likely more important in LIRGs

SFRS + LEGUS Comparison to Models



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